Astronomy magazine

Sky Guide 2016

By Martin Ratcliffe and Richard Talcott

Mars shines brilliantly and looms large through a telescope this year as it puts on its best display in more than 10 years. NASA/JPL/USGS

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A stellar year for Aldebaran

Ruddy Aldebaran sat to the upper right of a crescent Moon August 9, 2015. A gibbous Moon occults the same star January 19. Tunç Tezel

During its monthly orbit around Earth, the Moon passes in front of thousands of stars. Most of these distant suns are faint, however, and the so-called occultations that result pass with little notice. Just four 1st-magnitude stars — Aldebaran, Antares, Regulus, and Spica — lie close enough to the Moon's path to get in on the action. Aldebaran is 2016's clear winner, with the Moon occulting it a dozen times.

The best event for North American observers occurs the evening of January 19. Residents across Canada, most of the United States, and northwestern Mexico will see an occultation. Set up early and center Aldebaran in your telescope's eyepiece. Gradually, the dark limb of the waxing gibbous Moon will approach the star. Although most stars disappear from view instantaneously, Aldebaran is a red giant and likely will take a tenth of a second or so to fade out. The star's decline may be prolonged if you live where the occultation occurs near the Moon's curved northern or southern limb.

A few people will get to witness a drama-filled grazing occultation. If you view from a line that runs across northern Mexico and the U.S. Gulf Coast (see the map below), Aldebaran will skim the Moon's southern limb, ducking behind mountain ranges and reappearing in lunar valleys. This graze track is only a few miles wide, but serious observers often travel large distances to be in the path. Accurately timing when the star disappears and reappears gives astronomers precise information about the Moon's limb profile.

The Moon occults Aldebaran once each orbit this year, though not all of these events are created equal. Some of the occultations occur when the Moon and star lie below the horizon, and others when the Sun shares the sky and reduces the drama.

North American observers have seven opportunities to see Aldebaran pass behind the Moon during 2016. Events occur January 19, February 15/16 (western U.S. only), April 10 (daylight), July 29, August 25 (daylight), October 18/19, and December 12/13.

Because the Moon's orbit lies close to the path of the solar system's planets, Luna also occasionally occults one of Earth's neighbors. The best planetary occultation this year comes September 2 when a 1.5-day-old Moon hides Jupiter during daylight. Along a track from Oregon to the Texas coast, the planet grazes the northern lunar limb; people south of this line can view a complete occultation.

People north of a line that runs across northern Mexico and southern Texas to the Georgia coast will see the Moon occult Aldebaran on January 19.

All illustrations: *Astronomy*: Roen Kelly and Kellie Jaeger

2016 Jan

S	M	T	W	T	F	S
					1	◑
3	4	5	6	7	8	○
10	11	12	13	14	15	◑
17	18	19	20	21	22	●
24	25	26	27	28	29	30
◐						

- **3** The Moon passes 1.5° north of Mars, 2 P.M. EST
- **4** Quadrantid meteor shower peaks
- **5** Pluto is in conjunction with the Sun, 10 P.M. EST
- **6** Venus passes 6° north of Antares, noon EST
- The Moon passes 3° north of Venus, 7 P.M. EST
- The Moon passes 3° north of Saturn, midnight EST
- **8** Venus passes 0.09° north of Saturn, 11 P.M. EST
- **13** The Moon passes 2° north of Neptune, 10 A.M. EST
- **16** The Moon passes 1.5° south of Uranus, 1 A.M. EST
- **19** The Moon passes 0.5° north of Aldebaran, 10 P.M. EST
- **27** The Moon passes 1.4° south of Jupiter, 8 P.M. EST

Moon Phases

- ◑ First Quarter
- ● Full Moon
- ◐ Last Quarter
- ○ New Moon

- Events that can be viewed with **the naked eye**
- Events that can be viewed with **binoculars**
- Events that can be viewed with a **telescope**

Jupiter blazes across Leo

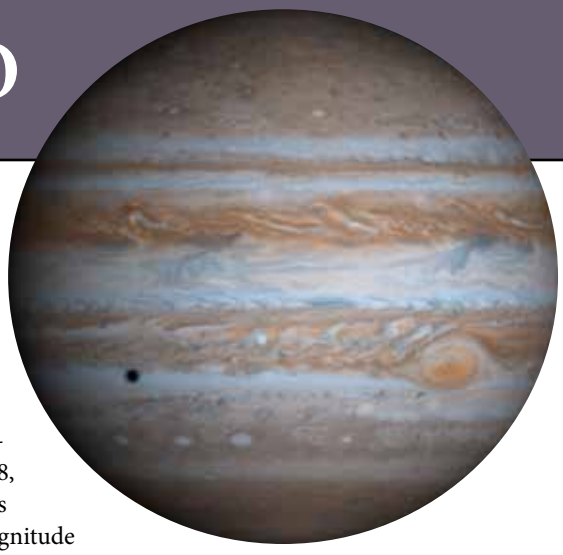
Jupiter puts on an impressive show throughout this winter and spring. Although it doesn't reach opposition and peak visibility until March 8, few observers will notice any difference in its appearance during the longer nights of January and February.

As 2016 opens, Jupiter dominates the late evening sky. It rises before 11 P.M. local time January 1 when it stands in eastern Leo next to that constellation's border with Virgo. The planet starts moving westward relative to the background stars just a week later, however, which carries it into the sparsely lit region of southeastern Leo. Shining brighter than magnitude –2, Jupiter is the lone standout.

The giant world's path has it heading straight for 4th-magnitude Sigma (σ) Leonis. On the night of March 2/3, the planet passes just 14' south of the star, and Jupiter appears as if it has gained a moon.

Jupiter reaches opposition March 8, when it shines brightest (magnitude –2.5) and remains visible all night. It is unmistakable in the east as soon as night starts to fall. The world also appears largest at opposition, spanning 44" across its equator, though it stays above 43" from early February to early April.

Any telescope delivers stunning views of the giant planet. The smallest instruments reveal two dark equatorial belts straddling a brighter zone that coincides with the planet's equator. Also look for Jupiter's four biggest moons, which change positions from night to night and often by the hour. If you don't see four bright dots near the planet, it means one or more of the moons is hiding behind Jupiter's disk or passing in front of it.

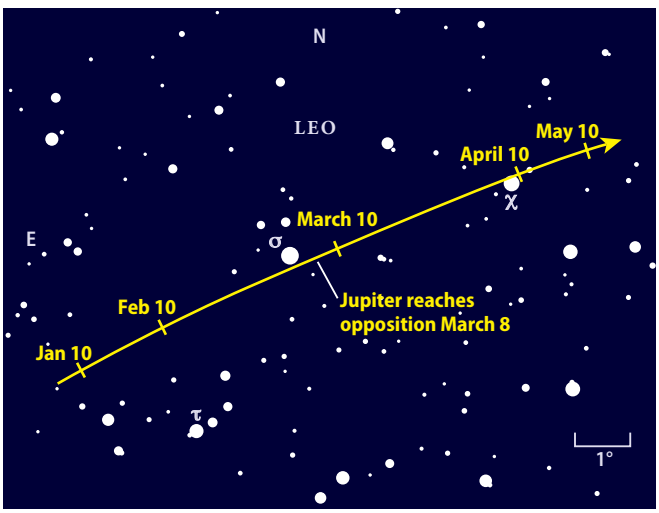


Jupiter will look striking through amateur telescopes in the first half of 2016. The planet's banded atmosphere and Great Red Spot stand out in this image, captured in December 2000 by the Cassini spacecraft. NASA/JPL/University of Arizona

Larger scopes reveal finer detail in the jovian atmosphere. A series of alternating bright zones and darker belts comes into view as do turbulent features in the swirl of clouds near the borders of these bands.

Jupiter remains a fascinating target throughout the spring. On April 7/8, it slides 7' north of 5th-magnitude Chi (χ) Leonis. And it remains on view past midnight local daylight time as late as early July.

Although it dips lower as summer progresses, keep an eye on Jupiter. On August 27, it has a fine conjunction with Venus. The sky's two brightest points of light then lie 5' apart and stand 5° above the western horizon 30 minutes after sunset. Jupiter passes behind the Sun in late September and a few weeks later returns to view before dawn, where it remains through the end of 2016.



The solar system's biggest planet shines brilliantly nearly all night this winter and spring. It spends this peak period in southeastern Leo, not far from the border with Virgo.

Feb 2016

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	○	9	10	11	12	13
14	◑	16	17	18	19	20
21	●	23	24	25	26	27
28	29					

1 The Moon passes 3° north of Mars, 4 A.M. EST

3 The Moon passes 3° north of Saturn, 2 P.M. EST

6 The Moon passes 4° north of Venus, 3 A.M. EST

The Moon passes 4° north of Mercury, noon EST

Mercury is at greatest western elongation (26°), 8 P.M. EST

9 The Moon passes 2° north of Neptune, 7 P.M. EST

12 The Moon passes 1.7° south of Uranus, 9 A.M. EST

16 The Moon passes 0.3° north of Aldebaran, 3 A.M. EST

23 The Moon passes 1.7° south of Jupiter, 11 P.M. EST

28 Neptune is in conjunction with the Sun, 11 A.M. EST

29 The Moon passes 4° north of Mars, 1 P.M. EST

2016 March

S	M	T	W	T	F	S
		◐	2	3	4	5
6	7	○	9	10	11	12
13	14	◑	16	17	18	19
20	21	22	●	24	25	26
27	28	29	30	◐		

2 The Moon passes 4° north of Saturn, 2 A.M. EST

3 Asteroid Ceres is in conjunction with the Sun, 5 P.M. EST

7 The Moon passes 4° north of Venus, 6 A.M. EST

8 Jupiter is at opposition, 6 A.M. EST

Total solar eclipse, 9 P.M. EST

10 The Moon passes 1.9° south of Uranus, 8 P.M. EST

14 The Moon passes 0.3° north of Aldebaran, 10 A.M. EDT

20 Equinox (northern spring/southern autumn begins), 1 A.M. EDT

Venus passes 0.5° south of Neptune, 10 A.M. EDT

21 The Moon passes 2° south of Jupiter, midnight EDT

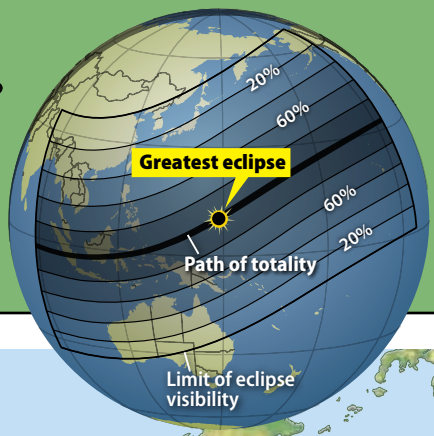
23 Penumbral lunar eclipse, 8 A.M. EDT

Mercury is in superior conjunction, 4 P.M. EDT

28 The Moon passes 4° north of Mars, 3 P.M. EDT

29 The Moon passes 3° north of Saturn, 11 A.M. EDT

Eclipse over Indonesia



Two solar eclipses grace Earth's sky in 2016, but the most spectacular will be the total eclipse of March 8/9. People along a narrow track that crosses parts of Indonesia and the Pacific Ocean will witness one of nature's greatest spectacles as the Moon completely blocks the Sun's bright disk and reveals our star's ethereal outer atmosphere, the corona.

The total eclipse begins when the Moon's dark umbral shadow first touches Earth at sunrise March 9 west of the Indonesian island of Sumatra. The shadow then island-hops for about 40 minutes, crossing Sumatra, Borneo, Sulawesi, and some smaller islands before heading northeast across the Pacific for another two-and-a-half hours. The eclipse peaks well out in the ocean, where the Moon hides the Sun's disk for 4 minutes and 9 seconds.

The March 9 path of totality crosses Sumatra, Borneo, and Sulawesi, as well as several smaller islands in the Indonesian archipelago.

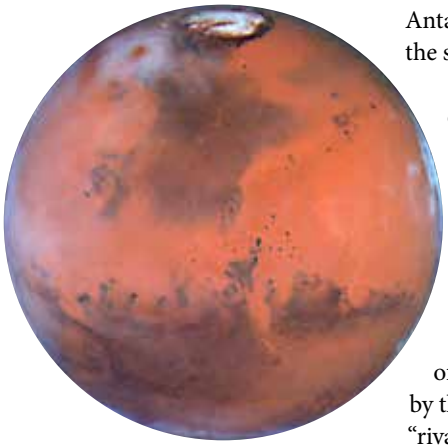
People in Hawaii will experience a significant partial eclipse late on the afternoon of March 8 — seemingly a day early because the Moon's shadow has crossed the International Date Line. From Honolulu, the eclipse begins at 4:33 P.M. HAST and lasts until 6:33 P.M. The Moon hides 70 percent of the Sun's diameter at the 5:37 P.M. peak, when the two objects stand 14° above the western horizon. At the same moment, observers along the Big Island's Kona coast will see a 64 percent partial eclipse.

Much of Alaska also falls under the Moon's shadow. From Anchorage, the eclipse starts at 5:38 P.M. AKST with the Sun 7° above the horizon and peaks at 6:12 P.M. Luna then covers 19 percent of the Sun's diameter.

The Moon and Sun align for the year's second solar eclipse September 1. Unfortunately, the Moon then lies farther from Earth than it did March 8/9 so it appears too small to cover the entire solar disk. Instead, people along a narrow path in central Africa will see the Moon pass directly in front of the Sun but fail to cover the whole disk, leaving a bright ring visible. This so-called annular eclipse peaks in southern Tanzania where the ring of sunlight lasts 3 minutes and 6 seconds.

A diamond ring flashes into brilliance during the November 14, 2012, total solar eclipse in Australia. Observers eagerly await similarly stunning sights from Indonesia on March 9. Mike Reynolds

The Red Planet returns to glory



Mars glows brightly this spring as it makes its closest approach to Earth since 2005. Steve Lee (University of Colorado)/ Jim Bell (Cornell University)/Mike Wolff (SSI)/NASA

After a wait of two years, Mars puts on another marvelous display in Earth's sky. But this isn't just any apparition for Earth's neighbor — the Red Planet shines brighter and appears larger through a telescope than at any time since 2005. The sign that good Mars viewing has begun comes when the planet ends its normal eastward motion relative to the background stars April 16 and starts its so-called retrograde loop.

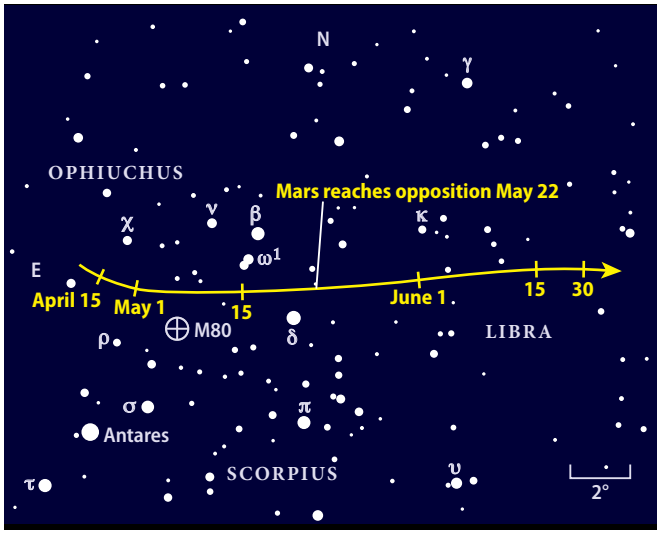
Mars then shines at magnitude –1.0 and spans 14" when viewed through a telescope. This is plenty big enough to show surface detail through a 4-inch instrument, though bigger scopes improve the view. The ruddy world rises around 11 P.M. local daylight time and appears highest in the south before dawn. Mars shares this region with magnitude 0.3 Saturn, which lies 7° to the east, and magnitude 1.1 Antares, which appears 5° to the south.

Be sure to check out the colors of the three objects. Saturn displays a yellow hue while the other two appear a similar shade of orange-red. By the way, the name Antares means "rival of Ares," Ares being the Greek god of war (the same role played by the Roman god Mars). The "rivalry" stems from the nearly identical colors.

During the next several weeks, Mars brightens rapidly and grows dramatically larger as it approaches opposition and peak visibility May 22. It glows brightest around opposition (peaking at magnitude –2.1) when it rises at sunset and remains visible all night. The planet appears slightly larger when it comes closest to Earth on May 30, cresting at an apparent diameter of 18.6". That's 22 percent bigger than at its previous peak in April 2014. Mars' diameter remains above 14" well into July.

The planet's large apparent size offers a visual feast for Mars' aficionados. Northern Hemisphere observers do face a challenge, however, because the world resides well south of the celestial equator and thus never climbs high in the sky. It peaks about 30° above the southern horizon from mid-northern latitudes.

Mars experiences seasons, but because its "year" is almost twice as long as Earth's, so are its seasons. The planet's northern hemisphere is in the midst of summer during the run-up to opposition, with the autumnal equinox arriving in early July. This means observers can follow the retreat of the north polar cap throughout this period. Also look for Syrtis Major, the most obvious dark feature on Mars' surface. Several other dark features show up during moments of good seeing.



The Red Planet spends the peak of its 2016 apparition moving westward against the background stars of Ophiuchus, Scorpius, and Libra.

2016 April

S	M	T	W	T	F	S
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3	4	5	6	○	8	9
10	11	12	◑	14	15	16
17	18	19	20	21	●	23
24	25	26	27	28	◐	30

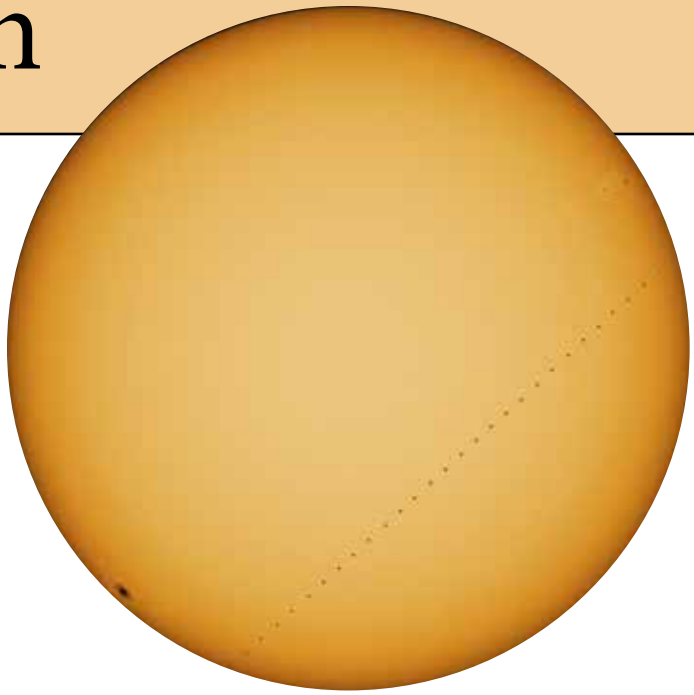
- **4** The Moon passes 1.9° north of Neptune, 9 P.M. EDT
- **6** The Moon passes 0.7° north of Venus, 4 A.M. EDT
- **8** The Moon passes 5° south of Mercury, 7 A.M. EDT
- **9** Uranus is in conjunction with the Sun, 5 P.M. EDT
- **10** The Moon passes 0.3° north of Aldebaran, 6 P.M. EDT
- **18** The Moon passes 2° south of Jupiter, 1 A.M. EDT
- Mercury is at greatest eastern elongation (20°), 10 A.M. EDT
- **22** Lyrid meteor shower peaks
- **24** The Moon passes 5° north of Mars, midnight EDT
- **25** The Moon passes 3° north of Saturn, 3 P.M. EDT
- **26** Asteroid Juno is at opposition, 11 P.M. EDT

May 2016

S	M	T	W	T	F	S
1	2	3	4	5	●	7
8	9	10	11	12	◐	14
15	16	17	18	19	20	○
22	23	24	25	26	27	28
◑	30	31				

- **2** The Moon passes 1.7° north of Neptune, 7 A.M. EDT
- **4** The Moon passes 2° south of Uranus, 11 P.M. EDT
- **5** Eta Aquariid meteor shower peaks
- **8** The Moon passes 0.5° north of Aldebaran, 5 A.M. EDT
- **9** Mercury transits the Sun, 11 A.M. EDT
- **15** The Moon passes 2° south of Jupiter, 6 A.M. EDT
- **21** The Moon passes 6° north of Mars, 4 P.M. EDT
- **22** Mars is at opposition, 7 A.M. EDT
- The Moon passes 3° north of Saturn, 6 P.M. EDT
- **23** Asteroid Vesta is in conjunction with the Sun, 3 P.M. EDT
- **29** The Moon passes 1.4° north of Neptune, 3 P.M. EDT

Mercury transits the Sun



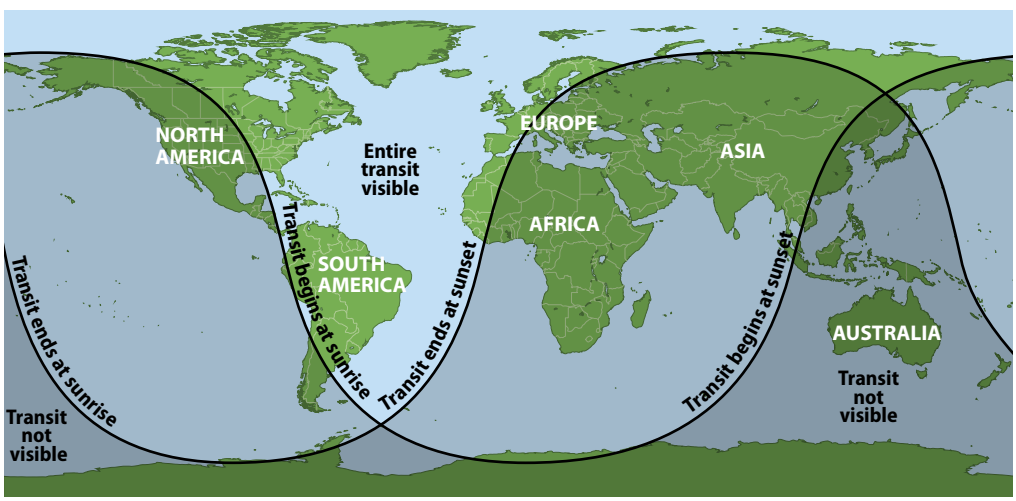
Mercury's tiny black disk crossed the Sun's face November 8, 2006, during the innermost planet's most recent transit of our star. Bill Hood

Transiting planets are all the rage. The Kepler spacecraft has discovered thousands of exoplanets by detecting the small drop in starlight that occurs when a planet passes in front of its parent sun. Well, this month you can see a transiting planet from your own yard! On May 9, Mercury transits the Sun for the first time since November 8, 2006. Observers across the Americas as well as in Europe, Africa, and much of Asia can view this event.

Transits of Mercury occur 13 or 14 times each century when the planet's orbit brings it directly between the Sun and Earth. Although Mercury zips around the Sun at an average speed of 107,000 mph, it will take the innermost planet 7.5 hours to cross the Sun's face May 9.

The event begins around 7:12 A.M. EDT, not long after the Sun rises in eastern North America. Mid-transit occurs about 10:57 A.M. EDT (7:57 A.M. PDT), well after sunup across the continent, when Mercury lies 319" from the center of the solar disk. The planet exits the brilliant disk around 2:42 P.M. EDT (11:42 A.M. PDT). These times are for a hypothetical observer at Earth's center; actual times may differ by a couple of minutes.

Mercury's disk spans 12", a tiny fraction of the Sun's 1,901" girth. You'll need a telescope to view the transit, but make sure to protect your eyesight. For a direct view, place a safe solar filter over your instrument's front end. Alternatively, you can project the Sun's image onto a white card to allow several people to view the transit simultaneously. Place the card 12 to 18 inches from the eyepiece to enlarge the Sun's disk and use sunspots or Mercury's disk to focus the image.



People across the Americas, Europe, Africa, and much of Asia can watch Mercury transit the Sun on May 9.

Saturn's summer splendor

Saturn's rings open wider this year than they have since 2004. At the planet's peak in early June, they tilt 26° to our line of sight and should look spectacular through any telescope. NASA/ESA/E. Karkoschka (University of Arizona)

On the heels of Mars' late May opposition, Saturn follows suit less than two weeks later. On June 3, the ringed planet lies opposite the Sun in our sky and remains on view all night. The majestic world spends the year within the confines of Ophiuchus, nestled between the brighter constellations Scorpius and Sagittarius.

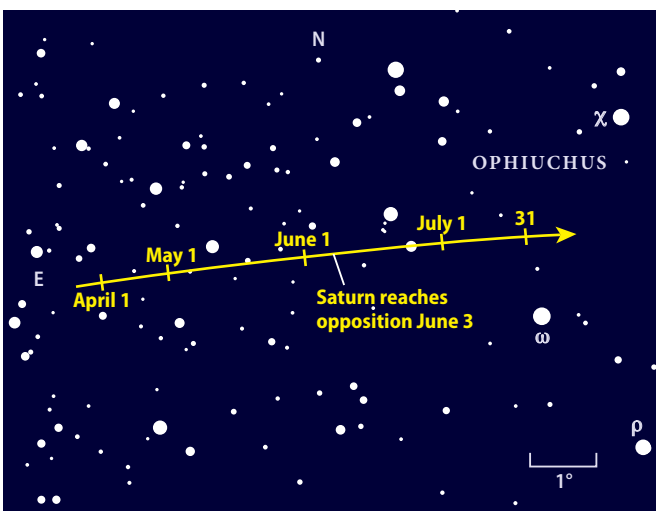
As you might guess, the proximity of their opposition dates means Mars and Saturn appear near each other in the sky. The two lie 7° apart in mid-April and then pull apart slowly as the Red Planet begins its more rapid retrograde loop. By the time Saturn reaches opposition in early June, 16° separate the two. Saturn then shines at magnitude 0.0, its brightest for the year. Although significantly dimmer than Mars, the ringed planet appears noticeably brighter than 1st-magnitude Antares to the south.

Saturn looks absolutely stunning through a telescope around opposition. The planet's subtly shaded yellowish disk measures 18.4" across while the spectacular rings span 41.8" and tilt 26° to our line of sight. The severe tilt offers exquisite views of the ring system's structure, including the dark Cassini Division that divides the outer A ring from the brighter B ring.

A small telescope also reveals an obvious companion — Saturn's 8th-magnitude moon, Titan. Several fainter moons orbit closer in. Easiest to spot are the 10th-magnitude trio of Tethys, Dione, and Rhea, which typically show up through 4-inch instruments. Enceladus glows at 12th magnitude and orbits closer to the rings, making it a challenge even in larger scopes.

Although Titan has a thick atmosphere with liquid hydrocarbon seas on its surface and Enceladus blasts plumes of water into space, Iapetus may well be the most intriguing saturnian moon. One of its hemispheres is as bright as snow while the opposite side appears as black as coal. During its 79-day orbit, Iapetus turns its diverse faces toward Earth. It shines at 10th magnitude when far west of the planet but two magnitudes dimmer when it's far to the east. Look for it around greatest western elongation the night of June 21/22.

Planetary motions bring Mars back to Saturn's vicinity in late August. The Red Planet passes 4° south of Saturn on the 25th, two days after Mars slides 2° north of Antares. Saturn has another pretty conjunction, this time with Venus, on October 29 and 30. The ringed planet then stands 3° north of its brilliant neighbor in the southwestern sky after sunset.



The ringed planet resides among the background stars of southwestern Ophiuchus at its best this year. The gas giant world peaks at magnitude 0.0 and shines noticeably brighter than any nearby star.

2016 June

S	M	T	W	T	F	S
			1	2	3	○
5	6	7	8	9	10	11
◑	13	14	15	16	17	18
19	●	21	22	23	24	25
26	◐	28	29	30		

1 The Moon passes 2° south of Uranus, 10 A.M. EDT

3 Saturn is at opposition, 3 A.M. EDT

The Moon passes 0.7° south of Mercury, 6 A.M. EDT

5 Mercury is at greatest western elongation (24°), 5 A.M. EDT

6 Venus is in superior conjunction, 6 P.M. EDT

11 The Moon passes 1.5° south of Jupiter, 4 P.M. EDT

17 The Moon passes 7° north of Mars, 6 A.M. EDT

18 The Moon passes 3° north of Saturn, 8 P.M. EDT

19 Mercury passes 4° north of Aldebaran, 5 P.M. EDT

20 Solstice (northern summer/southern winter begins), 7 P.M. EDT

25 The Moon passes 1.2° north of Neptune, 9 P.M. EDT

28 The Moon passes 3° south of Uranus, 7 P.M. EDT

July 2016

S	M	T	W	T	F	S
					1	2
3	○	5	6	7	8	9
10	◑	12	13	14	15	16
17	18	●	20	21	22	23
24	25	◐	27	28	29	30
31						

1 The Moon passes 0.4° north of Aldebaran, midnight EDT

6 Mercury is in superior conjunction, 11 P.M. EDT

7 Pluto is at opposition, 6 P.M. EDT

9 The Moon passes 0.9° south of Jupiter, 6 A.M. EDT

14 The Moon passes 8° north of Mars, 2 P.M. EDT

16 The Moon passes 3° north of Saturn, 1 A.M. EDT

Mercury passes 0.5° north of Venus, 2 P.M. EDT

23 The Moon passes 1.1° north of Neptune, 2 A.M. EDT

25 The Moon passes 3° south of Uranus, midnight EDT

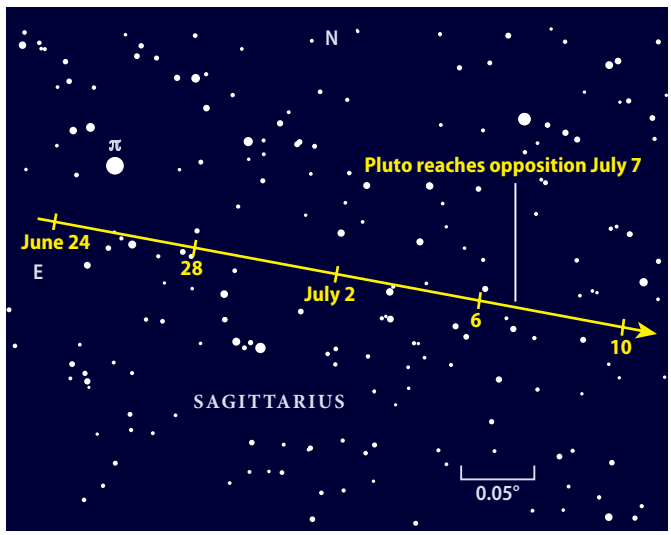
29 The Moon passes 0.3° north of Aldebaran, 7 A.M. EDT

30 Mercury passes 0.3° north of Regulus, 1 P.M. EDT

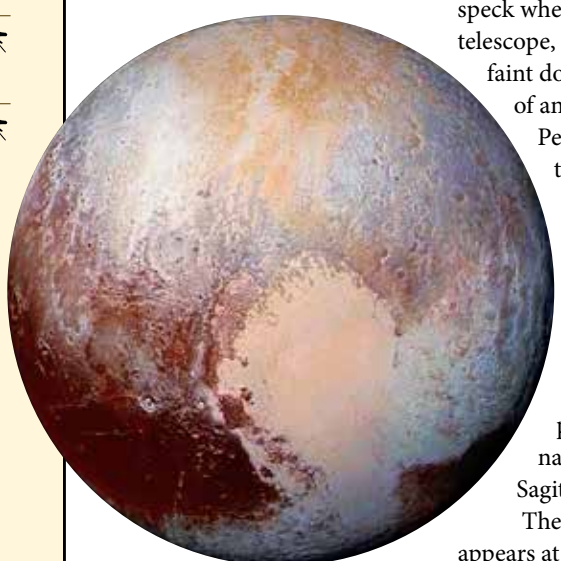
Tracking a recently exposed planet

The New Horizons spacecraft forever changed our perception of Pluto. Before the plucky probe flew past the distant dwarf planet, scientists knew little about this world beyond the presence of exotic surface ices, a thin escaping atmosphere, and five moons.

Millions of people around the world eagerly followed the historic July 2015 flyby. Breathtaking images revealed towering mountains of water ice, a vast equatorial glacier composed of frozen nitrogen and carbon monoxide, a heart-shaped ice region informally named Tombaugh Regio, ice flows, craters, and signs of recent geologic activity. Alan Stern of the Southwest Research Institute in Boulder, Colorado, principal investigator of New Horizons, captured the spirit of the moment during a press conference three days after the encounter when he said, "I think the solar system saved the best for last."



Northeastern Sagittarius is home to Pluto this year. The 14th-magnitude speck passes 2.7' south of Pi (π) Sagittarii on June 26.



Pluto emerged from the shadows in July 2015 when the New Horizons spacecraft flew past and returned the first close-up images of the distant world. NASA/JHUAPL/SwRI

The New Horizons revelations haven't changed the fact that Pluto looks like a dim speck when viewed through a telescope, but the sight of that faint dot now evokes images of an icy wonderland. People who never thought twice about observing the world now want to see it for themselves. Fortunately, the task proves easier this year than most thanks to Pluto's proximity to a naked-eye star in Sagittarius the Archer.

The solar system object appears at its best in late June and early July. It then glows dimly at magnitude 14.1, so you'll need an 8-inch or larger telescope to track it down. Luckily, the Moon is gone from the evening sky during this period. Your best chance for spotting Pluto in the eyepiece comes if you observe from a site far removed from the lights of the city.

Now you're ready to zero in on your target. Pluto lies in northeastern Sagittarius among a triangle of 3rd- and 4th-magnitude stars: Pi (π), Omicron (o), and Xi² (ξ²) Sagittarii. This tight group lies due north of the handle in the Archer's conspicuous Teapot asterism.

Use magnitude 2.9 Pi Sgr as your guide. On June 26, Pluto passes 2.7' due south of Pi. By the time the planet reaches opposition July 7, it has moved noticeably, to a position 18' west-southwest of the star. If you can't tell which point of light Pluto is, sketch five or six stars near its position and come back to the same field a night or two later. The "star" that moved is Pluto.

The Perseids in prime time

Three Perseid meteors streaked across the sky almost simultaneously at the peak of the 2015 shower. Jamie Cooper

The Perseid shower is a mainstay of the annual meteor calendar because it has a high rate of "shooting stars" and it occurs on warm summer nights. The shower peaks this year before dawn August 12, conveniently timed with the Moon out of the sky (the waxing gibbous sets around 1 A.M. local daylight time). That leaves more than three hours of darkness before twilight starts to paint the sky. The meteors appear to radiate from the constellation Perseus (hence the shower's name), a region that climbs high shortly before dawn.

The Perseids derive from debris laid down by Comet 109P/Swift-Tuttle. This periodic visitor returns to the inner solar system every 130 years or so, and each time it does, the Sun boils off some of its ices, releasing tiny dust particles in the process. Over the eons, these specks have spread out to fill the comet's orbit, and every August Earth plunges through the dense swarm. The particles enter our atmosphere at a blistering 37 miles per second and get incinerated by friction, creating the streaks of light.

In a typical year, observers under dark skies can see up to 100 meteors per hour at the peak if the radiant lies overhead. But astronomers think we might get an even better performance this year. Calculations show that Jupiter's gravity recently shifted part of the comet's dust stream closer to Earth's orbit, and our planet will be crossing this section in 2016. If so — and that's a big "if" — observers under optimal conditions could witness 150 meteors per hour.

You'll see the most meteors if you observe under a dark sky. Consider reclining in a lawn chair or lying on an air mattress. Look roughly two-thirds of the way from the horizon to the zenith and roughly 40° to 60° from the radiant.

The Perseids should be this year's finest meteor shower. Although January's Quadrantids and May's Eta Aquariids both occur under Moon-free skies, they don't typically produce as good a show. And bright moonlight will wash out the fainter members of October's Orionid, November's Leonid, and December's Geminid showers.

Meteor showers in 2016

Name	Peak date	Moon's phase	Prospects
Quadrantids	Jan. 4	Waning crescent	Good
Lyrids	April 22	Full Moon	Poor
Eta Aquariids	May 5	New Moon	Excellent
Perseids	Aug. 12	Waxing gibbous	Good
Orionids	Oct. 21	Waning gibbous	Poor
Leonids	Nov. 17	Waning gibbous	Poor
Geminids	Dec. 13	Full Moon	Poor

2016 Aug

S	M	T	W	T	F	S
	1	○	3	4	5	6
7	8	9	◑	11	12	13
14	15	16	17	●	19	20
21	22	23	◐	25	26	27
28	29	30	31			

4 The Moon passes 3° south of Venus, 2 A.M. EDT

The Moon passes 0.6° south of Mercury, 6 P.M. EDT

5 Venus passes 1.1° north of Regulus, 5 A.M. EDT

The Moon passes 0.2° south of Jupiter, midnight EDT

11 The Moon passes 8° north of Mars, 6 P.M. EDT

12 The Moon passes 4° north of Saturn, 8 A.M. EDT

Perseid meteor shower peaks

16 Mercury is at greatest eastern elongation (27°), 5 P.M. EDT

18 Penumbral lunar eclipse, 5 A.M. EDT

19 The Moon passes 1.1° north of Neptune, 8 A.M. EDT

20 Asteroid Pallas is at opposition, 8 A.M. EDT

22 The Moon passes 3° south of Uranus, 6 A.M. EDT

23 Mars passes 1.8° north of Antares, midnight EDT

25 The Moon passes 0.2° north of Aldebaran, 1 P.M. EDT

Mars passes 4° south of Saturn, 2 P.M. EDT

27 Venus passes 0.07° north of Jupiter, 6 P.M. EDT

2016 Sept

S	M	T	W	T	F	S
				○	2	3
4	5	6	7	8	◑	10
11	12	13	14	15	●	17
18	19	20	21	22	◐	24
25	26	27	28	29	○	

1 Annular solar eclipse, 5 A.M. EDT

2 Neptune is at opposition, 1 P.M. EDT

The Moon passes 0.4° north of Jupiter, 6 P.M. EDT

3 The Moon passes 1.1° north of Venus, 7 A.M. EDT

8 The Moon passes 4° north of Saturn, 5 P.M. EDT

9 The Moon passes 8° north of Mars, 10 A.M. EDT

12 Mercury is in inferior conjunction, 8 P.M. EDT

15 The Moon passes 1.2° north of Neptune, 4 P.M. EDT

16 Penumbral lunar eclipse, 3 P.M. EDT

17 Venus passes 3° north of Spica, 7 P.M. EDT

18 The Moon passes 3° south of Uranus, 1 P.M. EDT

21 The Moon passes 0.2° north of Aldebaran, 7 P.M. EDT

22 Equinox (northern autumn/southern spring begins), 10 A.M. EDT

26 Jupiter is in conjunction with the Sun, 3 A.M. EDT

28 Mercury is at greatest western elongation (18°), 4 P.M. EDT

29 The Moon passes 0.7° south of Mercury, 7 A.M. EDT

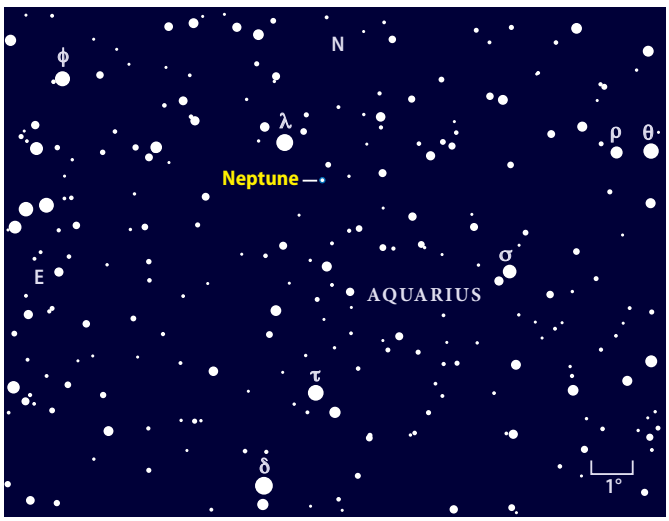
Ice giants come in from the cold

Two major planets dominate the outer solar system. Uranus has about 15 times the mass of Earth while Neptune tips the scale at 17 Earth masses. Scientists refer to the pair as "ice giants" to differentiate them from their larger gas giant cousins Jupiter and Saturn. (By "ice," astronomers mean they have large amounts of compounds such as water and methane in their interiors compared with the hydrogen and helium that dominate the gas giants.)

Both ice giants make tempting targets this autumn. Neptune reaches opposition and peak visibility September 2 while Uranus follows in mid-October. Identifying Neptune hasn't been this easy for years. After wandering through a star-poor region of southern Aquarius, this year the planet ventures close to magnitude 3.7 Lambda (λ) Aquarii. You can find Lambda 23° south of magnitude 2.5 Alpha (α) Pegasi, the star at the southwestern corner of the Great Square of Pegasus.

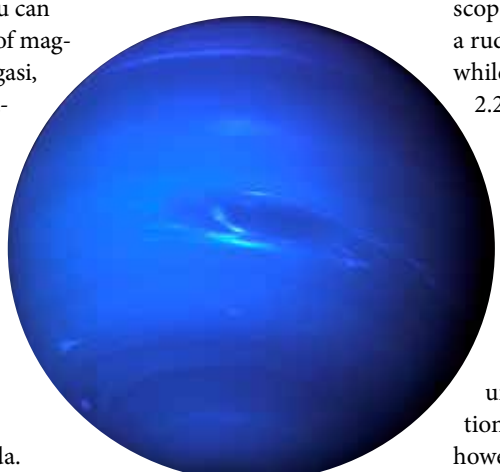
Neptune lies less than 2° southwest of Lambda throughout September. At opposition on the 2nd, the planet glows at magnitude 7.8, making it an easy binocular object in the same field as Lambda.

Neptune approaches even closer to Lambda in July. On the 11th, the planet appears 28' south-southeast of the star. And on the 24th, Neptune slides 31' due south of Lambda. The ice giant then rises around 10 P.M. local daylight time and appears highest before dawn. Once opposition arrives in September, it rises at sundown and is nicely placed by midevening.



The ice giant world Neptune resides among the background stars of Aquarius the Water-bearer this year. At opposition September 2, the magnitude 7.8 planet lies within 2° of 4th-magnitude Lambda (λ) Aquarii. The chart shows stars to magnitude 8.5, so identification should be a snap.

The planet spends the rest of 2016 in the evening sky to Lambda's southwest. But by year's end, it has a more notable companion. Mars' rapid eastward motion carries it within 13' of Neptune on New Year's Eve. Mars then shines at magnitude 0.9 and Neptune is some 630 times dimmer, at magnitude 7.9. Through a telescope, the Red Planet displays a ruddy disk that spans 5.7" while the ice giant appears 2.2" across and blue-gray.



Neptune shows a distinctive blue-gray cast when viewed through amateur telescopes. The color appeared even more dramatic to Voyager 2's cameras when the probe flew by in 1989. NASA/JPL

Uranus lies in southern Pisces, one constellation east of Neptune. Glowing at magnitude 5.7 at its October 15 opposition, Uranus shows up easily through binoculars and even to the naked eye under a dark sky. (Opposition does not offer a dark sky, however — the Full Moon lies a few degrees away.) The ice giant world spends October just north of a line joining the 5th-magnitude stars Zeta (ζ) and Mu (μ) Piscium.

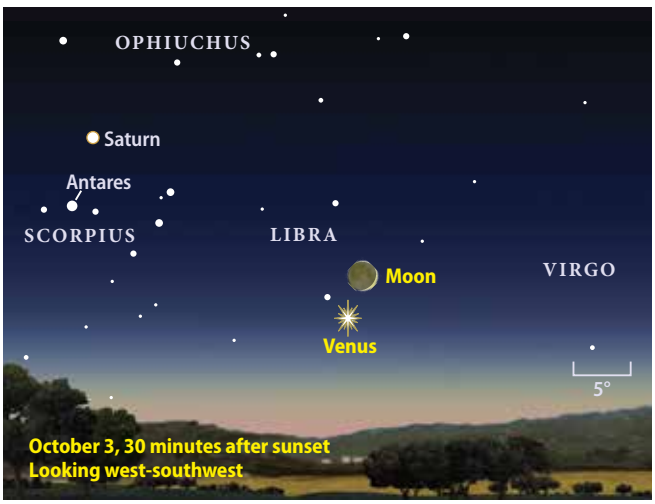
Brilliant Venus rules the evening sky

For one planet, 2016 is an odd year. Venus experiences no greatest eastern or western elongation, the first time this has happened since 2008. Every eight years, the inner planet reaches superior conjunction (passing on the far side of the Sun) in June. This means it reached western elongation in October 2015 and won't come to eastern elongation again until January 2017.

Following its June 6 superior conjunction, Venus returns to the evening sky. It shines brilliantly in the west during twilight in August and September, though it remains low. It finally climbs into a dark sky during October.

You'll want to be sure to look for it October 3, when a waxing crescent Moon passes within 5° of the planet. The pair lies about 10° high in the west-southwest a half-hour after sunset and remains an impressive sight for another 30 minutes. The Moon appears 8 percent lit while a telescope reveals that Venus is 85 percent illuminated. The Moon returns to the planet's vicinity twice more in 2016, and Venus shows a diminished phase each time. On November 2, the planet appears 77 percent lit and on December 3 it is 68 percent lit.

A waxing crescent Moon passed within a few degrees of Venus on the evening of September 8, 2013. The two brilliant objects will have a similarly stunning encounter October 3. Jared Bowens



Shortly after the Sun goes down October 3, look for brilliant Venus just below the waxing crescent Moon.

Venus spends the first half of October among the background stars of Libra, then crosses into Scorpius on the 17th and Ophiuchus on the 24th. One evening later, the world stands 3° north of 1st-magnitude Antares. And four nights after that, the planet passes 3° south of Saturn. At magnitude –4.0, Venus far outshines all its neighbors. The planet pushes into Sagittarius on November 9 and Capricornus on December 7, climbing higher into a darker sky with each passing week.

Venus also appears in the eastern sky before dawn early in the year. The premier winter event occurs January 9 when Venus passes a mere 5' north of Saturn. The pair rises more than two-and-a-half hours before the Sun.

Oct 2016

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
◑	10	11	12	13	14	15
●	17	18	19	20	21	◐
23	24	25	26	27	28	29
○	31					

- **3** The Moon passes 5° north of Venus, 1 P.M. EDT
- **6** The Moon passes 4° north of Saturn, 4 A.M. EDT
- **8** The Moon passes 7° north of Mars, 8 A.M. EDT
- **10** Mercury passes 0.9° north of Jupiter, midnight EDT
- **13** The Moon passes 1.2° north of Neptune, 2 A.M. EDT
- **15** Uranus is at opposition, 7 A.M. EDT
- The Moon passes 3° south of Uranus, 10 P.M. EDT
- **19** The Moon passes 0.3° north of Aldebaran, 3 A.M. EDT
- **21** Orionid meteor shower peaks
- Asteroid Ceres is at opposition, 1 A.M. EDT
- **25** Venus passes 3° north of Antares, midnight EDT
- **27** Mercury is in superior conjunction, noon EDT
- **28** The Moon passes 1.4° north of Jupiter, 6 A.M. EDT
- **30** Venus passes 3° south of Saturn, 4 A.M. EDT

Nov 2016

S	M	T	W	T	F	S
		1	2	3	4	5
6	◐	8	9	10	11	12
13	○	15	16	17	18	19
20	◑	22	23	24	25	26
27	28	●	30			

- **2** The Moon passes 4° north of Saturn, 3 P.M. EDT
- The Moon passes 7° north of Venus, midnight EDT
- **6** The Moon passes 5° north of Mars, 7 A.M. EST
- **9** The Moon passes 1.0° north of Neptune, 10 A.M. EST
- **12** The Moon passes 3° south of Uranus, 6 A.M. EST
- **15** The Moon passes 0.4° north of Aldebaran, noon EST
- **17** Leonid meteor shower peaks
- **18** Mercury passes 3° north of Antares, 4 P.M. EST
- **24** The Moon passes 1.9° north of Jupiter, 9 P.M. EST
- **29** Asteroid Juno is in conjunction with the Sun, 3 P.M. EST
- **30** The Moon passes 7° north of Mercury, 11 P.M. EST

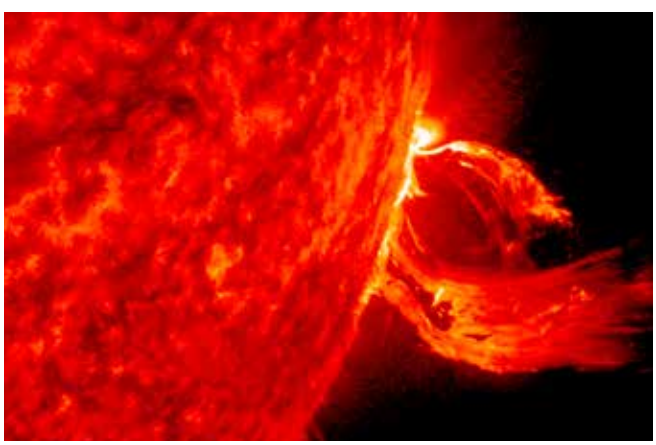
The Sun's dynamic face

With winter approaching and the nights growing colder, observers often shudder at the thought of spending hours under the stars. But there's a solution to this problem hiding in plain sight — our own star, the Sun. Not only does it provide plenty of light for viewing, but it's also up in the daytime. You can see amazing features through a small telescope and not lose any sleep — a true win-win situation!

The Sun's fierce brilliance makes safety a top concern, however. Direct sunlight can permanently damage your retina in a fraction of a second. To directly view the Sun, use only a safe solar filter that fits snugly over the front end of your telescope. If you use a Hydrogen-alpha (Hα) filter or scope, make sure all of its components are secure.

A view of the Sun in (filtered) white light can be mesmerizing. Sunspots stand out vividly. These dark, cooler regions in the solar photosphere (its visible surface) change appearance from day to day and sometimes by the hour. Isolated spots are common, but dozens can gather in complex active regions. Sunspots arise when strongly bunched magnetic fields impede the regular flow of heat from the solar interior.

Dark filaments snake across the Sun's disk while orange-red prominences arch above the solar limb in this Hydrogen-alpha image. Craig and Tammy Temple



You never know what you might see when viewing the Sun. Here, a solar prominence gives birth to a coronal mass ejection. SDO/NASA

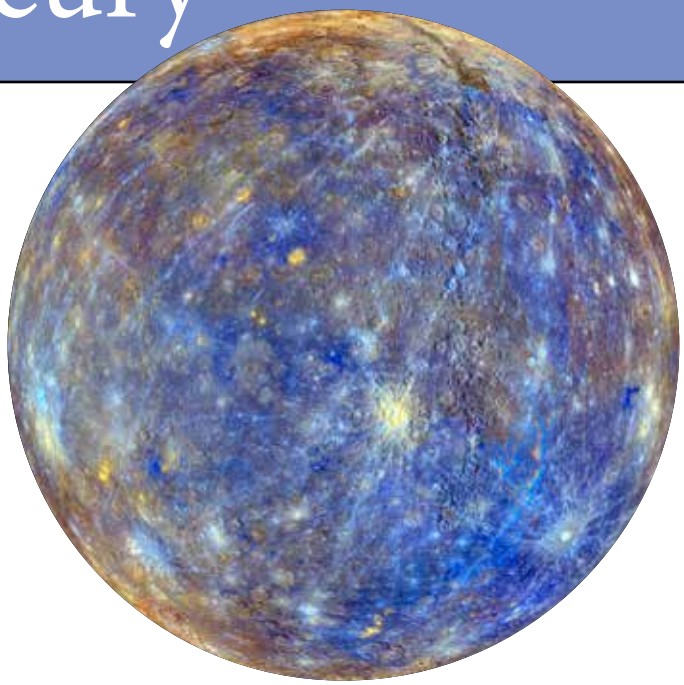
Under good seeing conditions, you also may see granulation. Continual churning of hot gases in the solar photosphere causes this rice-grain pattern. Rising columns of hot gas appear slightly brighter than the cooler descending regions that surround them.

In contrast to a white-light filter, a Hα filter reveals additional features by transmitting only red light at a wavelength of 656.3 nanometers. Dark filaments appear to snake across the surface, created by magnetic fields raising cooler hydrogen gas into high arches that look black against the solar disk. When viewed at the Sun's limb, however, these arches appear as bright protrusions called "prominences" that can change by the minute. Hα filters also reveal bright "plages" surrounding sunspots and on rare occasions a solar flare.

A fleeting glimpse of Mercury

Mercury swings through Sagittarius during the first half of December in one of its best evening shows of the year. Because the innermost planet follows a Sun-hugging orbit, it appears low in the sky shortly after sunset or before sunrise when near a greatest elongation from our star. Its visibility also depends on the angle of the ecliptic — the apparent path of the Sun and planets across the sky — to the horizon, with steeper being better.

You can first glimpse Mercury on December 1. Look for a two-day-old Moon hanging some 15° above the southwestern horizon a half-hour after sunset. Using binoculars, then drop 10° directly below the Moon to pick up Mercury. The planet shines brightly enough, at magnitude –0.5 (as it does for the next two weeks), to pierce the twilight glow.

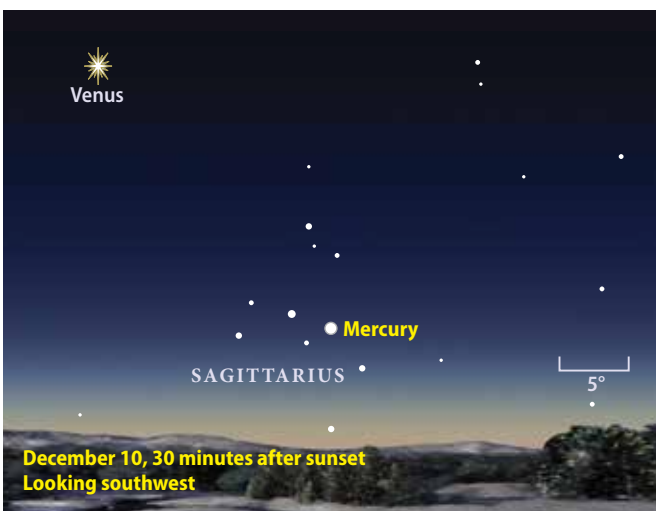


Mercury glows in false colors in this image from the MESSENGER spacecraft, whose mission ended April 30, 2015. Through amateur scopes, the innermost planet shows a featureless disk. NASA/JHUAPL/CIW

As Mercury crosses Sagittarius, it seems to gain a moon December 7. The intruder is actually a star, magnitude 2.8 Lambda (λ) Sagittarii, which forms the top of the lid in the constellation's Teapot asterism. From North America, the two pass within 9' of each other. Use binoculars or a small telescope for the best view.

Mercury reaches greatest elongation December 10 when it lies 21° east of the Sun. That evening, you can find the world nearly 10° high in the southwest 30 minutes after sunset. It maintains this altitude for another week but then drops toward the Sun and dims rapidly. It disappears about a week before passing between the Sun and Earth on the 28th.

Mercury's speedy orbital motion guarantees several apparitions during the course of the year. It appears somewhat higher and in a darker sky on evenings around its April 18 greatest elongation but barely scrapes the horizon at its August 16 best. The planet's top morning apparition comes in late September when it climbs about 10° high in the east a half-hour before sunrise.



Look for Mercury low in the southwestern sky after sunset during the first half of December. It reaches peak visibility at greatest elongation on the 10th, when the planet lies about 25° to the lower right of brilliant Venus.

Dec 2016

S	M	T	W	T	F	S
				1	2	3
4	5	6	◑	8	9	10
11	12	●	14	15	16	17
18	19	◐	21	22	23	24
25	26	27	28	○	30	31

3 The Moon passes 6° north of Venus, 8 A.M. EST

5 The Moon passes 3° north of Mars, 6 A.M. EST

6 The Moon passes 0.7° north of Neptune, 5 P.M. EST

9 The Moon passes 3° south of Uranus, 3 P.M. EST

10 Saturn is in conjunction with the Sun, 7 A.M. EST

Mercury is at greatest eastern elongation (21°), midnight EST

12 The Moon passes 0.5° north of Aldebaran, midnight EST

13 Geminid meteor shower peaks

18 The Moon passes 1.0° south of Regulus, 2 P.M. EST

21 Solstice (northern winter/southern summer begins), 6 A.M. EST

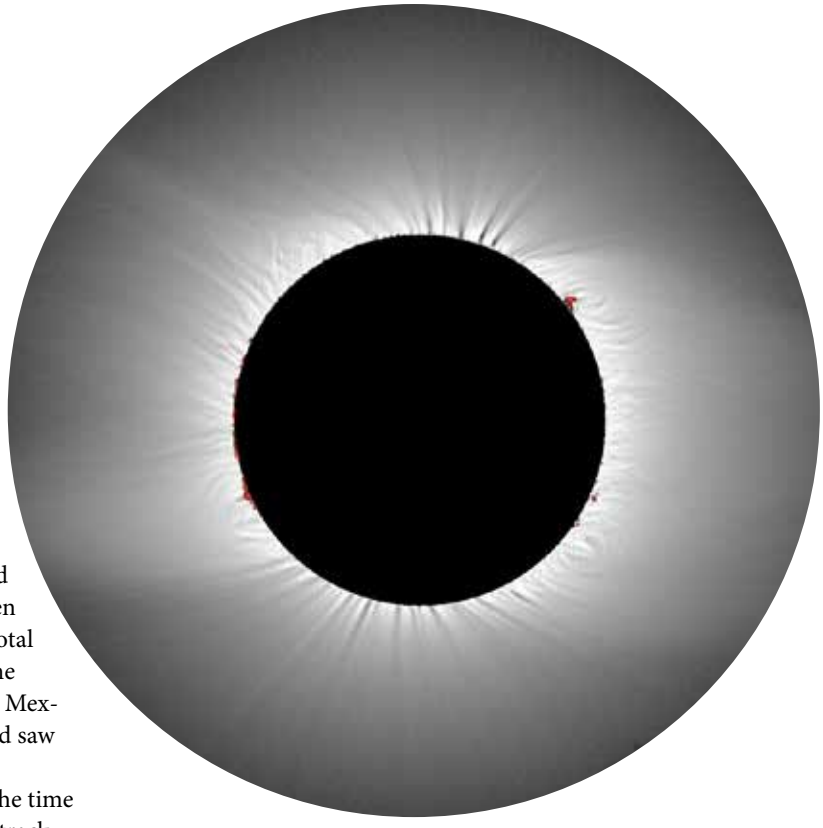
22 The Moon passes 2° north of Jupiter, noon EST

27 The Moon passes 4° north of Saturn, 4 P.M. EST

28 Mercury is in inferior conjunction, 2 P.M. EST

2017 preview

Looking ahead to next year...



The Sun's ghostly corona and fiery-red prominences show up beautifully during a total solar eclipse. Patrick Martinez

The long wait is over. On August 21, 2017, the United States will be at the center of the astronomical universe when the Moon's dark umbral shadow creates the country's first total solar eclipse in 26 years. But that tells only half the story. The July 11, 1991, eclipse touched just Hawaii before heading to Mexico and then south to Brazil. The last time the U.S. Mainland saw totality was February 26, 1979.

But the decades-long drought will be long forgotten by the time the Moon's umbra sweeps coast to coast on August 21. The track first hits land in Oregon. (Coincidentally, that state's capital, Salem, is in the path of totality this year as it was in 1979.) From there, the shadow speeds southeast across the country in approximately 90 minutes until exiting on the South Carolina shore. Totality's greatest duration occurs in southern Illinois, where the Moon completely hides the Sun's bright disk for 2 minutes and 40 seconds. Still, anyone on the center line will see at least 119 seconds of totality. Observers across the rest of North America can see a partial eclipse, but let's be real — if you have any interest in astronomy, you need to be in the path of totality on August 21.

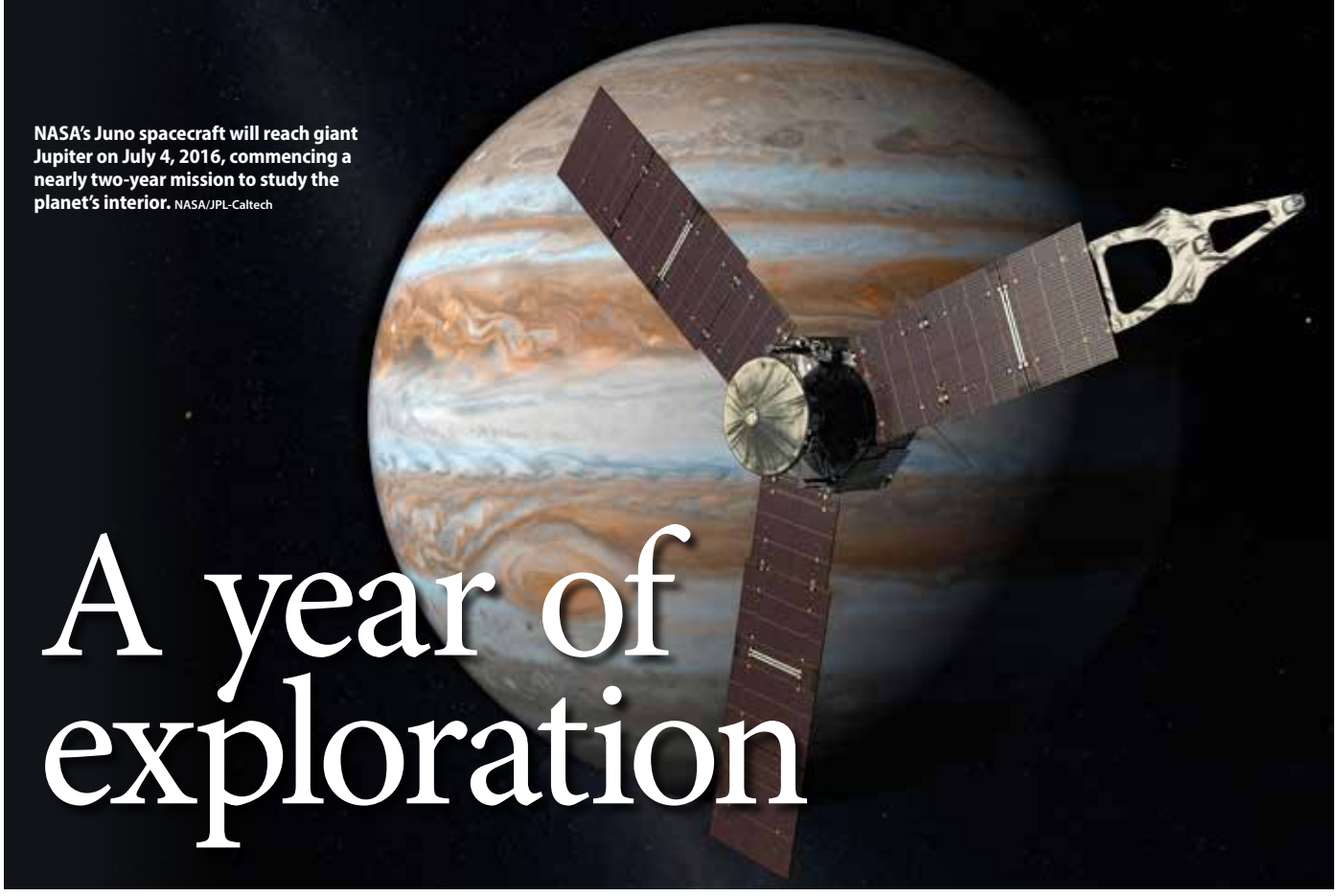
Two other eclipses of note occur in 2017, though both pale in comparison. An annular solar eclipse — in which the Moon appears a bit too small to cover our star, leaving a ring of sunlight visible — arrives February 26. The path crosses southern South America and the Atlantic Ocean before ending in southern Africa. And Earth's shadow partially hides the Moon on August 7. It is the first partial or total lunar eclipse in 23 months.

Observers with a penchant for planets have three to keep them satisfied. Venus puts on a marvelous show on evenings in early 2017. At greatest elongation January 12, it shines brilliantly in the southwest as darkness falls and doesn't set until four hours after the Sun. Jupiter and Saturn also put on great shows in 2017. Giant Jupiter reaches peak visibility in April while ringed Saturn follows two months later. Saturn in particular stands out. At opposition June 15, its ring system tilts 26.6° to our line of sight — the steepest angle at any opposition since 2002. The large tilt will afford telescope owners exquisite views of ring structure.

The 2017 meteor calendar also looks a bit brighter than it did in 2016. Two of the year's most prolific showers — January's Quadrantids and December's Geminids — occur within a few days of New Moon, as do the reliable Orionids of October and Leonids of November. Of the best showers, only the Perseids (which peak under a waning gibbous Moon) fare poorly.

The path of the first total solar eclipse to touch the U.S. Mainland in 38 years cuts across the country from Oregon to South Carolina on August 21, 2017.

The Moon dips into Earth's dark umbral shadow for the first time in nearly two years on August 7, 2017. Steve Gabino



NASA's Juno spacecraft will reach giant Jupiter on July 4, 2016, commencing a nearly two-year mission to study the planet's interior. NASA/JPL-Caltech

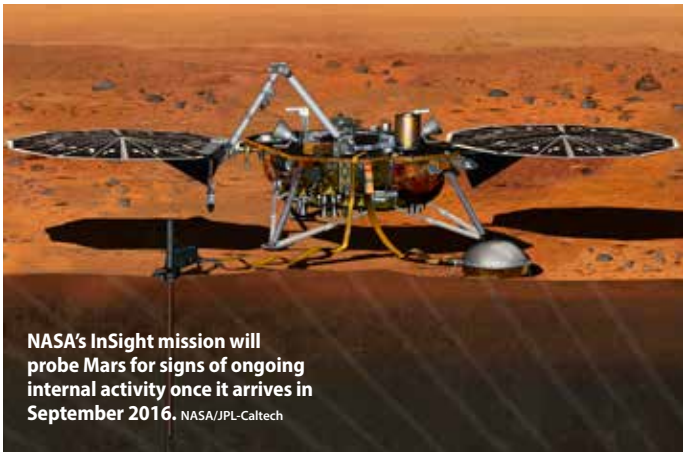
A year of exploration

While 2015 saw New Horizons fly past Pluto, completing the initial reconnaissance of the solar system's nine traditional planets, 2016 will see the first dedicated mission to Jupiter in more than a decade. NASA's Juno spacecraft arrives at the giant planet July 4 following a five-year trek. Although Juno has a camera and should take some incredible close-up images, the mission's main goal is to study the gas giant's interior by mapping the planet's magnetic and gravity fields. The probe will pass within a few thousand miles of the cloud tops during each of its 32 orbits.

NASA also plans to target its favorite subject — Mars — in 2016. Scheduled to launch in March and land in September, InSight will measure the heat flowing through the planet's surface and search for seismic activity. The craft's design is based on that of the successful Phoenix lander from 2008. The European Space Agency (ESA), in cooperation with Russia's Roscosmos, also plans a Mars mission in 2016. The ExoMars Trace Gas Orbiter will study minor atmospheric constituents possibly linked to current geologic and biologic activity. The orbiter also will deploy a lander, named Schiaparelli, to test ESA's ability to reach the martian surface.

These new probes join seven others currently operating on and above the Red Planet. And readers should expect plenty more from the flotilla of spacecraft scattered throughout the solar system. NASA's Cassini craft will continue to study Saturn and its rings and moons as it heads toward mission completion in 2017. Dawn will maintain its orbital reconnaissance of dwarf planet Ceres for at least the first few months of 2016. ESA's Rosetta probe will scrutinize Comet 67P/Churyumov-Gerasimenko until September. And New Horizons, which accomplished its Pluto flyby in July 2015, will return new data through most of the coming year.

The rapid pace of planetary exploration shows no signs of abating in 2016. You can count on seeing all the new results in the pages of *Astronomy*.



NASA's InSight mission will probe Mars for signs of ongoing internal activity once it arrives in September 2016. NASA/JPL-Caltech

NASA's Dawn spacecraft will continue to study Ceres, and this intriguing conical mountain, during early 2016. NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

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